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Craniofacial Reconstruction of the Indus Valley Civilization Individuals Found at 4,500-Year-Old Rakhigarhi Cemetery

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Abstract

Despite academic efforts to study the Indus Valley Civilization (IVC), there have as yet been no successful attempts to unveil the IVC people's craniofacial appearance. We investigated the IVC cemetery area of Rakhigarhi site, which was estimated to be of 2273 ± 38 and 2616 ± 73 years BCE. By craniofacial reconstruction (CFR) procedure using computed tomography (CT) data of two Rakhigarhi skulls (A1 BR02 and A2 BR36), we successfully reconstructed the faces of the IVC individuals who were buried about 4,500 years ago. This is the first attempt to unveil scientifically accurate representations of IVC people's actual facial morphology.

Keywords Indus Valley Civilization · Craniofacial reconstruction · Rakhigarhi cemetery · Computed tomography · India

Introduction

The Indus Valley Civilization (IVC) is known as one of the earliest civilizations in the world. Archaeological remains of IVC have been discovered throughout a vast area spanning India, Afghanistan and Pakistan (Shinde 2016). Actually, in some ancient societies, physiognomies have often been estimated via close examinations of portraits. This kind of artistic tradition, however, was poorly developed in IVC society. At best, anthropomorphic figurines made of terracotta have indicated the preferred style of costume and adornments. Therefore, there have as yet been no successful data to unveil the IVC people's facial appearance. In this regard, we note the craniofacial reconstruction (CFR) technique, which has been employed in the field of anatomy and forensics to approximate the faces of deceased individuals. In the present study, we carried out CFR on the skulls obtained from the cemetery at Rakhigarhi, one of the largest cities of the time (Shinde et al. 2018). Since there have as yet been no successful attempts at craniofacial reconstruction of IVC individuals, this is the first attempt to unveil scientifically accurate representations of IVC people's actual facial morphology.

Case report

Rakhigarhi (N29°17′52.9″/E76°06′51″) is the site of an ancient city located in the Hisar district of the state of Haryana, India (Fig. 1). We performed archaeo-anthropological analyses on the IVC cemetery area in 2013-2016 (Shinde et al. 2018). The date estimation was done by accelerator mass spectrometry (Inter University Accelerator Center, New Delhi, India): 2273 ± 38 years BCE and 2616 ± 73 years BCE (Mature IVC period) for charcoal specimens collected at the site (Shinde et al. 2018). The Archaeological Survey of India permitted this excavation (approval number: F/15/1/2010 EE). During our excavation of Rakhigarhi burials, we found 37 individuals finally subjected to anthropological examination; and there were 9 individuals with more than half of the skull preserved (Shinde et al. 2018).

Among the Rakhigarhi skeletons, two skulls (7.2 A1 BR02 and 7.2 A2 BR36) were selected for the present CFR (Fig. 2). The individuals were buried in supine position at each grave (Fig. 3). The skeletal remains were then transported to and housed at the Deccan College Post Graduate and Research Institute (Deemed University), India. A review of the Institutional Review Board (IRB) about this

research was exempted by Seoul National University Hospital (exemption number: 2013-004; 2017-001).

Anthropological information about the Rakhigarhi individuals is summarized in Table 1 and is also available in previous reports (Shinde et al. 2018; Woo et al. 2018). Sex and age were estimated by the techniques described in *The Standards for Data Collection* (Buikstra and Ubelaker 1994). Once the skulls BR02 and BR26 were scanned by computed tomography (CT) (Siemens, Erlangen, Germany), the data were formatted in Digital Imaging and Communication in Medicine (DICOM), which were further converted into stereolithography (STL) images using 3D visualization computer software (InVesalius, Brazilian Ministry of Health, Brazil). After they were imported into 3D computerized modelling software (Geomagic Freeform, 3D Systems, USA), the face reconstruction of the skeletonized individuals was performed in accordance with the method of Wilkinson (2014).

To prepare the CFR, missing or damaged skull parts were reconstructed according to the assumption of a symmetrical body structure (Fig. 4; Figs. 5A and 5B). At the skin surface layering stage, we used the average facial soft-tissue depths (FSTD) data for the Indian population group representative of northwest Indian adults (Sahni et al. 2008). Virtual tissue-depth pegs were located on the surface of the skull model at the corresponding anatomical landmarks in the 3D modelling software (Fig. 5C). Major facial muscles were rebuilt following the relevant anatomical references in terms of its origin and insertion point. At this stage, pre-modeled facial muscles (n=15) and parotid glands were utilized. The shapes and sizes of the muscles were amended with deformation tools to customize them to the corresponding skulls (Fig. 5D).

To predict the facial components including the eyes, eyebrows, nose, mouth and ears, multiple sets of guidelines were referenced. We followed the referenced guidelines (Guyomarc'h et al. 2012; Fedosyutkin and Nainys 1993; Angel 1978) for the prediction of the eyes and eyebrows (Table 2). The position and morphology of the nose were predicted following the standards of Rynn et al. (2009). The position and shape of mouth were estimated with reference to the maxillary canine and first premolar teeth (Krogman and İşcan 1986). The lip thickness was derived from regression equations based on the positive correlation between the enamel heights of the upper and lower incisors and lip thickness (Wilkinson et al. 2003). The ears were predicted following the standards of Fedosyutkin and Nainys (1993). The breadth of the ears was estimated according to the length of the nose. The angle of the ear

was set as parallel to the jaw line. The earlobe adherence was predicted based on the direction of the mastoid process (Fedosyutkin and Nainys 1993). Facial components were rebuilt onto the skull as specified above (Fig. 5D).

At the final stage of facial reconstruction, the skin layer was added over the muscular and skeletal structures in reference to the facial anatomy, utilizing the transparency tools available in the Geomagic Freeform® (3D Systems Inc., Rock Hill, South Carolina, USA). Figure 5E shows the facial components utilized in the reconstruction. Figure 5F to 5J and Movie Clips (Supplementary Data 1 and 2) also display the completely reconstructed heads of Rakhigarhi individuals BR02 and BR36.

Discussion

Reports have provided detailed information on the rise and fall of the IVC over a timeline subdivided into Early (5,500-2,600 BCE), Mature (2,600-1,900 BCE), and Late (1,900-1,500 BCE) periods. During the Mature period, ancient major cities prospered as the regional politico-cultural centers of the civilization (Shinde 2016). Over the last century, archaeologists have discovered several IVC cemetery sites around the towns or cities (Shinde et al. 2018). With obtained data on the cemetery skeletal remains, anthropologists studied the lives of the IVC population in more detail, most of which have focused on the physical (Kenoyer et al. 2013) and pathological (Lukacs 2017; Schug 2017) features of the IVC people.

Revealing what the people looked like has proved to be one of the most important tasks for researchers interested in the IVC. However, this demand has not easily been met, particularly as IVC cemeteries and graves have not been investigated sufficiently to date. The anthropological data obtained from IVC skeletons still falls short of what would be needed for any comprehensive account in this respect. Also, as noted above, no artistic likenesses of individuals in terms of portraiture have been found or analyzed other than IVC figurines. Actually, *the Priest-King*, a famous figurine found at Mohenjo-daro, might be on exception. The male bust had been depicted with a close-cropped beard, half-closed eyes, an encrusted diadem around his head, and a robe of trefoil design. However, it is not an accurate representation of this population's facial morphology (During Caspers 1985).

In this context, our present report provides invaluable information to related scholars because

CFR has been utilized to reconstruct the faces of forensically or anthropologically important people (Wilkinson 2004). Previous empirical studies on CFR's qualitative and quantitative accuracy have demonstrated that the technique provides sufficient resemblances (only small errors less than 2.0 mm) to actual forensic or historical figure's faces thereby reconstructed (Claes et al. 2010; Fernandes et al. 2012; Lee et al. 2012). Therefore, the CFR technique is increasingly used for archaeo-anthropological researches nowadays particularly when there is little information available to recreate historically important people's faces (Wilkinson 2004). This means that its inaugural reconstruction of the facial appearances of approximately 4,500-year-old IVC skulls by CFR technique can also provide enough resemblance to Rakhigarhi individuals' actual faces to enable recognition.

In this study, we also showed that it is a CFR to recreate the dead individual's ante-mortem appearance by rebuilding his/her face onto a skull of Rakhigarhi individuals. For the first time ever, the present study can afford us anthropologically accurate representations of IVC people's real facial morphology. Our report is an anthropologically very important because there is no information about IVC people's craniofacial morphologies to date. Despite this achievement, however, this study also has its limitations. To obtain a knowledge that offers us a detailed understanding of the IVC people's facial appearance, additional CFR studies should also be undertaken in the future. Since only a small number of Rakhigarhi skeletons' faces were tried in the present study, more cases from wider areas of IVC cemeteries still remain to be reconstructed.

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Figure Legends

Figure 1. Geography of Rakhigarhi site (red dot). Black dots represent the IVC sites where human skeletons were discovered at the cemetery.

Figure 2. Archaeological site of Rakhigarhi cemetery. The graves of skeletons for which CFR was done are marked in red color.

Figure 3. Skeletons found at Rakhigarhi cemetery that were used for CFR in this study. (**A**) 7.2 A1 BR02. (**B**) 7.2 A2 BR36. (**C**) and (**D**) are magnified image of BR02 and BR36, respectively.

Figure 4. Reconstruction of missing portions based on the assumption of symmetry. (**A**) 7.2 A1 BR02; (**B**) 7.2 A2 BR36. The skull images of left column for original CT scanned images; right column for the images after reconstruction of absent parts. Arrows indicate the missing portions that were reconstructed by us.

Figure 5. Craniofacial reconstruction process of Rakhigarhi cemetery individuals (BR02 and BR36). (**A**) CT scanned image of skulls. (**B**) Reconstructing the missing portions of skulls. (**C**) Placing tissue depth pegs on the skull surface. (**D**) Positioning facial muscles. (**E**) Predicting facial components. **(F) to (J)** Finalizing craniofacial reconstruction by adding the skin layer over the muscle and skull structures. **(F)** Anterior, **(G)** lateral, **(H)** posterior, **(I)** superior and **(J)** inferior views of completely reconstructed heads.

Supplementary Data

Supplementary Data 1. Movie_Clip: CFR result of 7.2 A1 BR02

Supplementary Data 2. Movie_Clip: CFR result of 7.2 A2 BR36

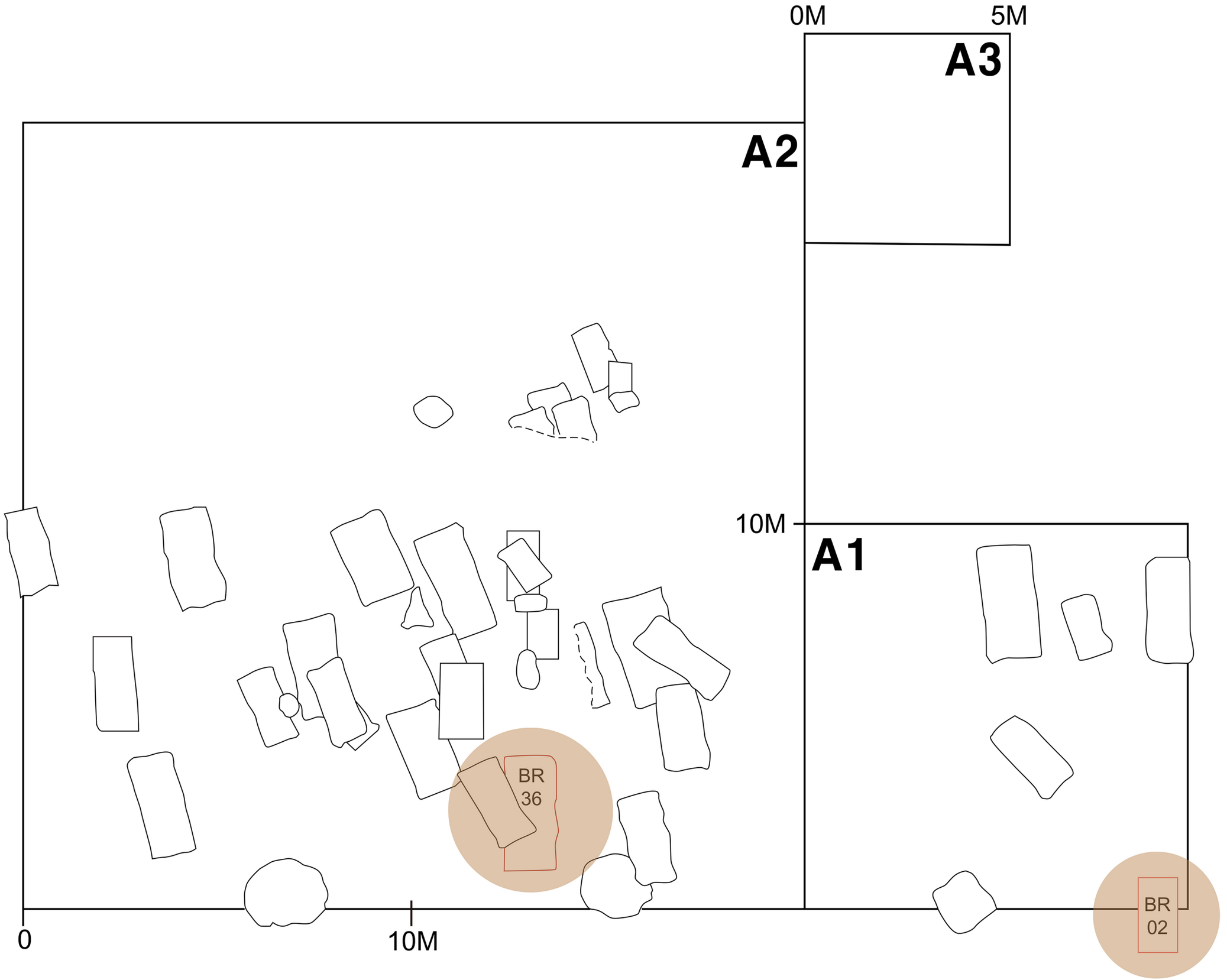
Table 1. Anthropological information of Rakhigarhi individuals reconstructed in this study

Locality	Trench	Burial No.	Sex	Age	Stature Estimated
RGR 7.2	A1	BR02	M	16-18	177.28 ± 3.24
	A2	BR36	F	36-50	167.07 ± 4.25

Table 2. Referenced Guideline for prediction of the eyes and eyebrows

Prediction	Guidelines	References
Position of the Eyeballs	25 mm diameter globes were placed inside the orbits; The eyeball and pupil were superior-laterally located.	Guyomarc'h et al. (2012)
Degree of Eyeball Protrusion	Calculated by the method suggested by Guyomarc'h et al. (2012).	Guyomarc'h et al. (2012)
Location of Eye Fissure	Determined by the rule that the endocanthus can be placed 2 mm lateral to the lacrimal crest at its middle, and that the exocanthus can be placed 3-4 mm medial to the malar tubercle. In cases where the malar tubercle was absent, the exocanthus was positioned 10 mm below the line of the zygomatico-frontal suture and 5-7 mm from the orbital margin.	Fedosyutkin and Nainys (1993) Angel (1978)
Shape and Placement of the Eyebrows	Following the suggestions of Fedosyutkin and Nainys (1993).	Fedosyutkin and Nainys (1993)


Afghanistan
Pakistan
Iran
India
Damb Sadaat
Nal
Shahi Tump
Sutkagen-dor
Harappa
Ropar
Rakhigarhi
Kalibangan
Farmana
Tarkhanwala Dera
Dholavira
Lothal
200km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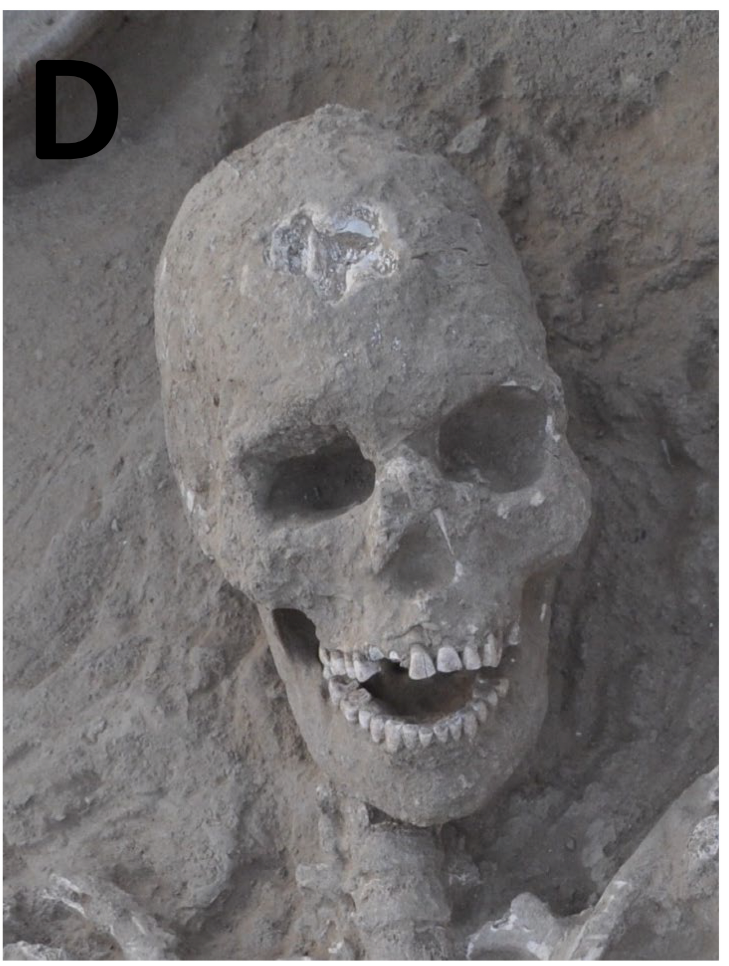
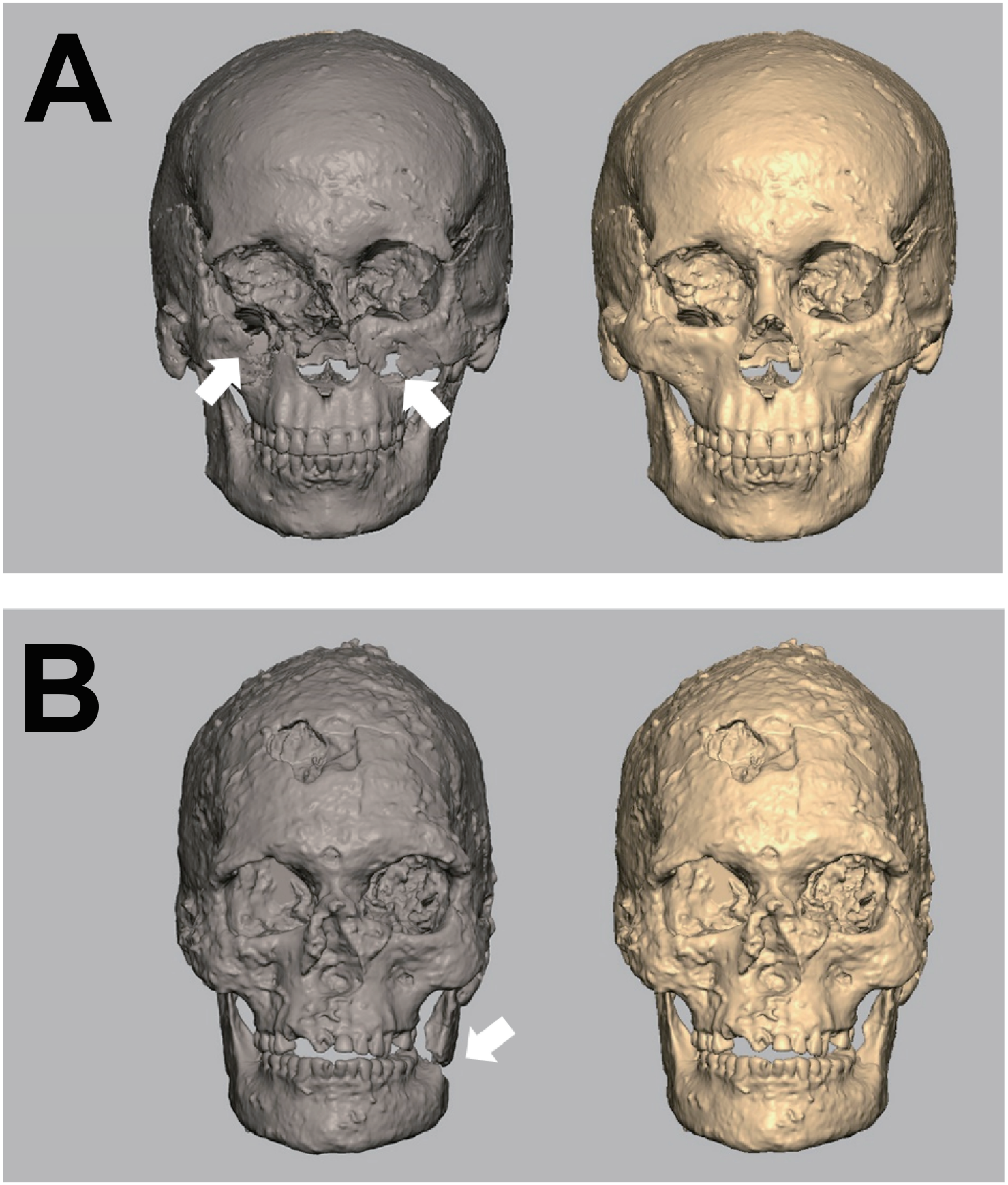
5M
A3
A2
10M
A1
BR
36
BR
02
0
10M


A


B
N

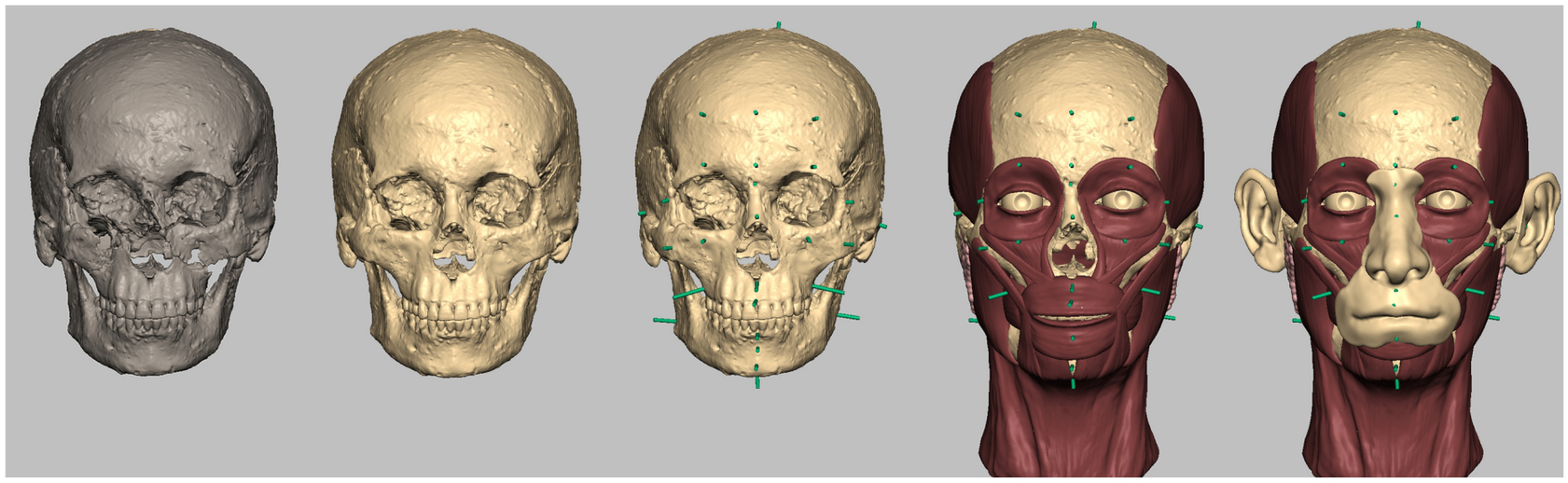

C


D

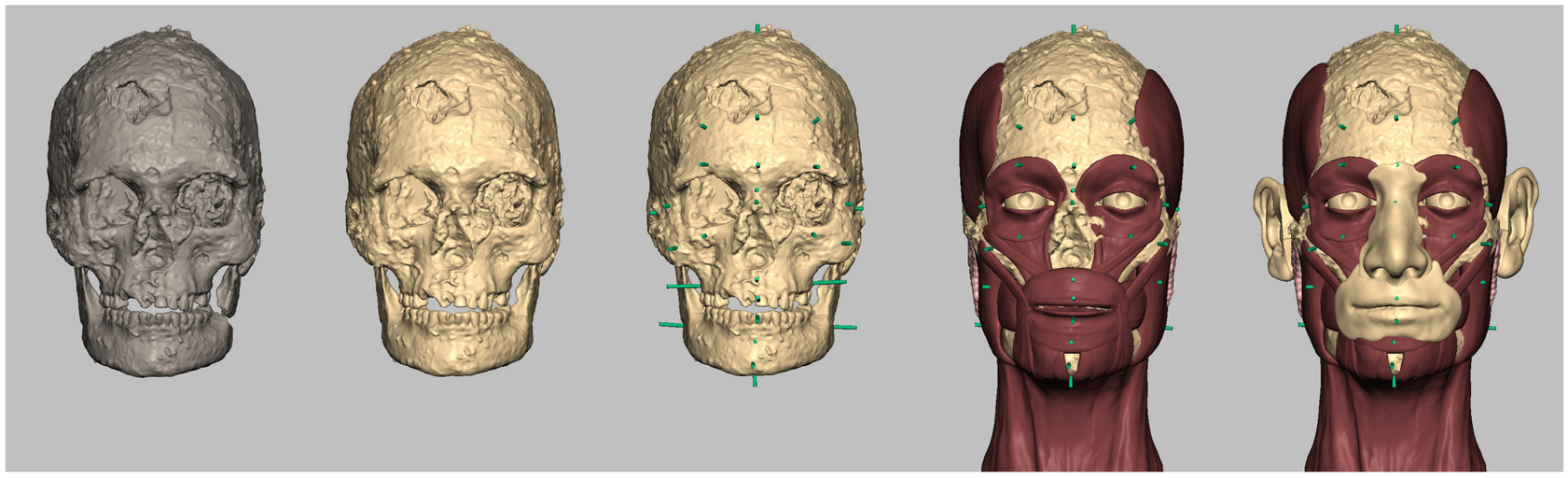

A
B

A B C D E

7.2 A1
BR02

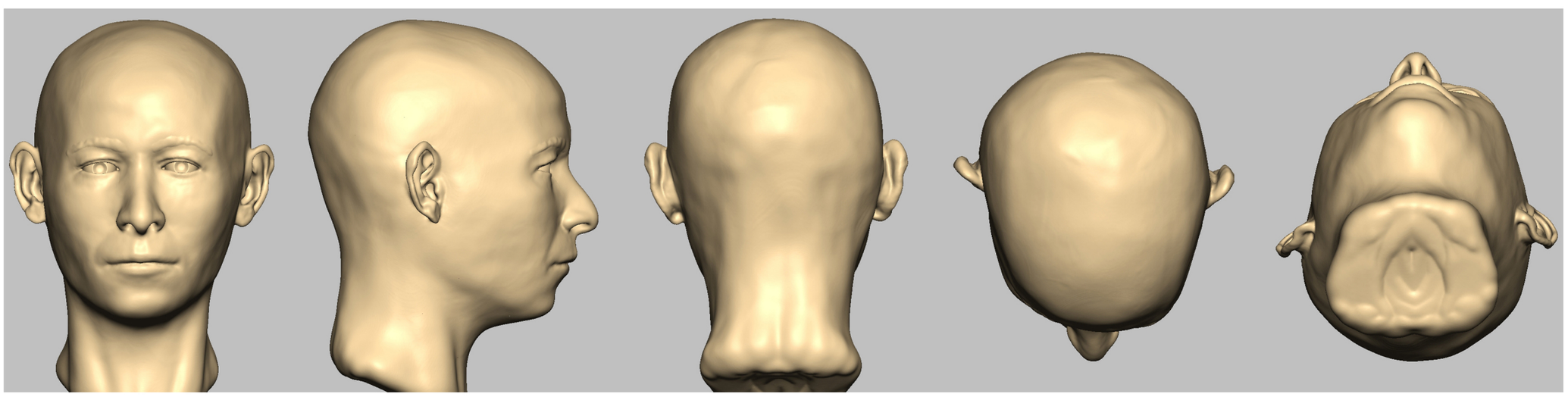


7.2 A2
BR36



F G H I J

7.2 A1
BR02



7.2 A2
BR36